Preventing deaths from pesticide self-poisoning—learning from Sri Lanka's success

WHO estimates that over 800 000 people die by suicide each year, with the majority of these deaths occurring in low-income and middle-income countries (LMICs).[1] During the late 1990s and early 2000s an estimated 35% of suicides, or 300 000 deaths, were due to intentional pesticide self-poisoning.[2] These numbers have since fallen,[3] but WHO still considers pesticide self-poisoning to be one of the three most important means of global suicide.[1]

In order to achieve further reductions, prevention efforts will need to be multifaceted and work across three levels: patient, community, and nation.[4] Improved medical management could reduce deaths after exposure; however, clinical trials have shown few benefits and many patients die before accessing health care. Improved storage of pesticides in households or community storage facilities may reduce access at moments of stress; this approach has been tested but has little supporting evidence of benefit thus far.[5] It is also possible that home-based storage schemes will conversely increase access due to farmers shifting their pesticide stores from fields to their homes and the lockable storage devices highlighting the whereabouts of poisons (in boxes that are often left unlocked).[6]

The most effective prevention efforts so far have been legislative. The restriction of highly hazardous pesticide (HHP) use in agriculture has shown beneficial effects on pesticide suicides across Asia,[7–9] most strikingly in Sri Lanka. Before the Green Revolution, which saw the introduction of high-yielding crop varieties into LMICs alongside the heavy marketing of pesticides and fertilisers from the 1960s onwards, the annual Sri Lankan suicide rate was quite stable at around 5 per 100 000 people older than 8 years (figure). With the introduction of HHPs in the 1960s, the suicide rate steadily rose to 24 per 100 000 in 1976, followed by a more dramatic rise after 1977 that coincided with Sri Lanka relaxing import trade restrictions. Between 1983 and 1995 the suicide rate plateaued, with a peak rate of 57 per 100 000 in 1995.

The Registrar of Pesticides noted this effect of pesticides and started banning the most toxic HHPs, initially parathion and methylparathion, in 1984. The exponential rise in total (not just pesticide) suicides then stopped (figure); the rate began to fall rapidly after 1995, when five further HHPs were banned, including two organophosphorus insecticides, methamidophos and monocrotophos, that had become particularly popular after the 1984 bans. Unfortunately, agricultural practice, and therefore self-poisoning, switched to an organochlorine insecticide, endosulfan,[3] which had to be banned in 1998. After this ban was introduced, the suicide rate fell further (figure).[7] The realisation that dimethoate, fenthion, and paraquat had become responsible for the majority of pesticide deaths in the 2000s resulted in them being banned in Sri Lanka during 2008–11. This ban, together with small improvements in medical management,[10] resulted in further decreases in the total suicide rate[8] (figure), as well as reductions in case fatality for pesticide poisoning in hospital wards.[10]

Sri Lanka's pesticide regulations appear to have contributed to one of the greatest decreases in suicide rate ever seen. Having peaked at 57 per 100 000 people over 8 years in the early 1990s, its incidence is now 17 per 100 000 each year, a 70% reduction, and continuing to fall. Using regression modelling techniques similar to those used previously,[9] we estimate that 93 000 lives were saved in Sri Lanka between 1995 and 2015 (appendix). The annual costs for the Office of the Registrar of Pesticides in the early 2000s was about US$200 000 (Manuweera G,

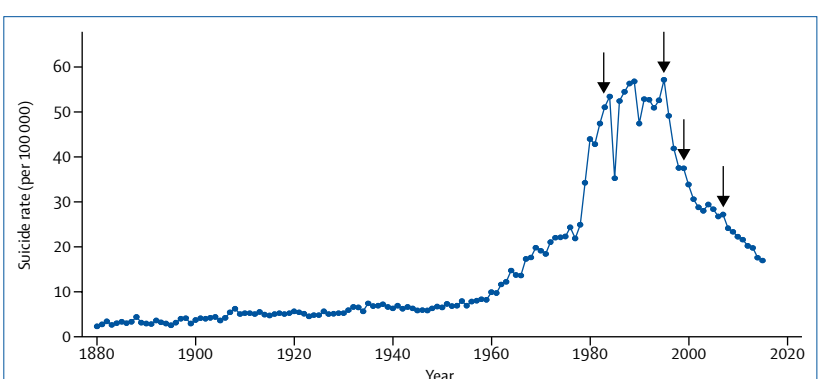

Figure: **Incidence of suicide in Sri Lanka, 1880–2015**
Arrows show timing of pesticide bans (1984: parathion, methylparathion; 1995: all remaining WHO class I toxicity pesticides, including methamidophos and monocrotophos; 1998: endosulfan; 2008: dimethoate, fenthion, paraquat). Suicide data were obtained from police records.

Secretariat of the Basel, Rotterdam, and Stockholm Conventions, personal communication). Considering only direct costs, each life was therefore saved at a cost of $43. With the median age at death from pesticide poisoning for women and men being 27 and 42 years, and life expectancy 79 and 72 years, respectively, with men comprising 77% of suicides,[11] the numbers of disability-adjusted life-years (DALYs) saved can be estimated at 3·26 million, at a direct cost to the government per DALY of $1·23 (appendix).

See Online for appendix

In 2013, 194 of WHO's member states adopted the Comprehensive Mental Health Action Plan 2013–2020, which has the target of reducing the suicide rate by 10% by 2020. Given that Sri Lanka achieved a 70% reduction in total suicide rate, at remarkably low direct costs and without apparent effect on agricultural yield,[12] improved pesticide regulation offers a clear route towards rapid attainment of this target.

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During 2003–11, DG was a member of scientific advisory groups for Syngenta-funded studies to assess the toxicity of a new paraquat formulation, a pesticide self-storage project, and trial of the medical management of paraquat poisoning; he received travel costs to attend research meetings but no other fees. He was an expert adviser to WHO's First Consultation on Best Practices on Community Action for safer access to pesticides (Geneva, 2006). DK is an Economic and Social Research Council (UK) postdoctoral fellow (ES/P009735/1).

1 WHO. Preventing suicide. A global imperative. Geneva: World Health Organization, 2014.
2 Gunnell D, Eddleston M, Phillips MR, Konradsen F. The global distribution of fatal pesticide self-poisoning: systematic review. *BMC Public Health* 2007; **7:** 357.
3 Mew EJ, Padmanathan P, Konradsen P, et al. The global burden of fatal self-poisoning with pesticides 2006–15: systematic review. *J Affect Disord* 2017, **219:** 93–104.
4 Roberts DM, Karunarathna A, Buckley NA, Manuweera G, Sheriff MHR, Eddleston M. Influence of pesticide regulation on acute poisoning deaths in Sri Lanka. *Bull World Health Organ* 2003; **81:** 789–98.
5 WHO. Safer access to pesticides for suicide prevention. Experiences from community interventions. Geneva: World Health Organization, 2016.
6 Konradsen F, Dawson AH, Eddleston M, Gunnell D. Pesticide self-poisoning: thinking outside the box. *Lancet* 2007; **369:** 169–70.
7 Gunnell D, Fernando R, Hewagama M, Priyangika WDD, Konradsen F, Eddleston M. The impact of pesticide regulations on suicide in Sri Lanka. *Int J Epidemiol* 2007; **36:** 1235–42.
8 Knipe DW, Chang SS, Dawson A, et al. Suicide prevention through means restriction: impact of the 2008–2011 pesticide restrictions on suicide in Sri Lanka. *PLoS One* 2017; **12:** e0172893.
9 Cha ES, Chang SS, Gunnell D, Eddleston M, Khang YH, Lee WJ. Impact of paraquat regulation on suicide in South Korea. *Int J Epidemiol* 2016; **45:** 470–79.
10 Dawson A, Gawarammana I, Jayamanne S, Manuweera G, Buckley N. Translational research: the effects of pesticide ban policy on poisoning epidemiology and deaths in Sri Lanka. NAACT abstract. *Clin Toxicol* 2016; **54:** 664.
11 Knipe DW, Metcalfe C, Fernando R, et al. Suicide in Sri Lanka 1975–2012: age, period and cohort analysis of police and hospital data. *BMC Public Health* 2014; **14:** 839.
12 Manuweera G, Eddleston M, Egodage S, Buckley NA. Do targeted bans of insecticides to prevent deaths from self-poisoning result in reduced agricultural output? *Environ Health Perspect* 2008; **116:** 492–95.